

Assessment of Groundwater Quality of Rural Areas of Allahabad District, India

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Abstract

Ground water resources are faced with an unprecedented risk of contamination, either due to leaching of metal from underground minerals or release of large quantities of industrial effluents throughout the world. Currently, about 20% of the world's population lacks safe drinking water according to United Nations Environmental Program (UNEP, 1999). Groundwater is the most important natural resource required for drinking for many people around the world, especially in rural areas. The resource cannot be optimally used and sustained unless the quality of groundwater is assessed.

A study on assessment of water quality of Allahabad District was conducted for 400 nos. of samples which were collected from 40 habitations of twenty blocks (two habitations from each blocks). The 16 water quality parameters (physical, chemical, and bacteriological), including iron, fluoride, hardness, total alkalinity, and arsenic, were analysed after bringing samples under controlled conditions from various, remotely placed habitations in the environmental engineering laboratory of the civil engineering department. The results were compared with the desirable limits of particular parameters as recommended by BIS: 10500 (91). The results showed that most of the sources were found to be contaminated by pathogenic organisms as per MPN test. The fluoride concentrations were found in excess of permissible limits in Shankargarh and Kondhiyara blocks. Iron concentrations were found too high in Shankargarh, Jasra, Soraon, and Mauaima blocks. The hardness of water samples tested was also high in Shankargarh, Jasra, and Mauaima blocks. The total alkalinity of Manda, Pratappur, Phulpur, Mauaima, and Holagarh blocks were found to be too high with reference to the desirable limit. The samples of Shankargarh and Bahadurpur blocks have shown higher arsenic concentration per new WHO guidelines.

Based on assessment and testing of the quality of the groundwater of the Allahabad District, the quality is doubtful and requires preventive measures be taken before supplying water to the rural people. Therefore, sufficient precautions must be taken by concerned authorities to search for alternative sources, or treatments, of present sources to make it potable.

Keywords: *Assessment, groundwater, fluoride, hardness, arsenic, iron*

Introduction

India is heading towards a freshwater crisis, mainly due to improper management of water resources and environmental degradation, which has led to a lack of access to safe water supply to millions of

people. The freshwater crisis is already evident in many parts of India, varying in scale and intensity depending on the time of the year. Water, being a universal solvent, carries minerals in solution,

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though present in small quantities. The quantity and composition of the dissolved minerals in natural water depends upon the type of rock or soil with which it has been in contact, or through which it has passed, and the duration of time it has been in contact with these rocks. Development of groundwater also provides opportunities to perfect its quality. Quality of groundwater may vary from place to place and from stratum to stratum. It also varies from season to season. The determination of suitability of groundwater would therefore involve a description of the occurrence of the various constituents and their relation to the usage. Water quality in the rural drinking water supply has emerged as a major issue which needs proper attention.

The principal reason for monitoring water quality has traditionally been the need to verify whether the observed water quality is suitable for intended uses (Bartram and Ballance, 1996). The government of India launched the National Rural Drinking Water Quality Monitoring and Surveillance Program in February 2006. The drinking water supply in rural India was chosen for the study. India is failing to apply standard water quality control methods developed over almost a century ago in Europe and North America. Drinking water surveillance programmes usually collect a wide range of information on water supplies. These include quality of water and sanitary risk, continuity of supply, quantities of water used, cost of water, and access to water supply. The surveillance of water quality is an important task in rural areas where hand pumps are a major source of water in the absence of a piped water supply. The contamination situation is going to become grimmer due to unhygienic conditions prevailing in areas surrounding hand pumps.

Geographic information system (GIS) is a system for storing and manipulating geographical information on a computer. A geographic information system lets us visualize, question, analyze, interpret, and understand data to reveal relationships, patterns, and trends. GIS helps to identify and map critical areas of land use and reveal trends that affect water quality. GIS is a powerful tool for developing solutions for water resources, such as

assessing water quality and managing water resources on a local or regional scale. By collecting the related graphs, data, and literal materials, the researcher digitized the graphs by means of Map GIS software. After editing and registering, the researcher organized and stored the spatial data through the thematic layer of GIS and put the related attribute data in the database. This established the basic spatial database of the studied region, which includes the thematic layer of the water system. GIS based systems can provide a visualization platform that leads to source monitoring of water quality for better water quality management. It can provide scientific decision making and technical support for emergency cases if applied to the whole water distribution network.

Study Area and Methodology

Study Area

The water samples were collected from 40 villages of Allahabad District. The Allahabad District of Uttar Pradesh is located at latitude from 24.85 to 25.73 [decimal degrees] and longitude from 81.38 to 82.20 [decimal degrees] at an elevation/altitude of about 80 meters. Allahabad District is divided into 20 Blocks, and from each block, two villages were selected for sampling. From the selected villages, 10 habitations were shortlisted based on population distribution and geographical coverage. Figure 1 presents the different block boundaries of Allahabad District from where samples were collected for testing.

Sample Collection and Transportation

Hand pump water samples were collected in 1.0 L PVC water bottles after operating a hand pump for approximately 15 minutes. Collected water samples were immediately stored in a Chill Pack container at 2°C and were transported to the laboratory under chilled conditions. For biological parameter (MPN), all samples were collected from the hand pump in a sterilized BOD bottle, capped immediately, and stored in a Chill Pack container at 2°C during transit. All precautions were taken to avoid any post-contamination during collection and transportation of water samples.



Figure 1: Different Block Boundaries Map of Allahabad District

Table 1

List of Water Quality Parameters under Water Quality Monitoring

Parameter	Methodology
Fluoride	Fluoride
Chloride	Potassium chromate / silver nitrate
Iron	Spectrophotometer
Nitrate	UV Spectrophotometer/ VIS/ Ion Chromatograph
Total Hardness (Ca and Mg)	Titration
Residual Chlorine	OT/DPD
Total Coli form	MPN with multiple fermentation
Turbidity	Nephelometer
pH	pH meter
TDS	Gravimetric
Colour	Colour Units
Odour	TON
Taste	Flat
Alkalinity	Titration
Conductivity	Conductivity Meter
Arsenic	Arsenic Testing Kit

Sample Testing

In the laboratory, the water samples were preserved in a fridge at 2°C. Before testing, samples were brought to room temperature after being taken out of the fridge. The samples were tested per Standard Methods (1989) in the Environmental Engineering Laboratory of Civil Engineering Department of the MNNIT, Allahabad, India for 16 water quality parameters. The list of these 16 water quality parameters, along with their testing methodologies, is given in Table 1. However, in this paper, results of only four critical parameters (i.e. fluoride, total hardness, iron, and arsenic) have been discussed and compiled on GIS platform.

Sampling Methodology

There are three steps for performing water sampling:

Step-1: Calculation of sample size

Step-2: Stratification

Step-3: Location of sample sites

Step-1: For identifying the ideal sample size

$$n = \frac{4P(1-P)D}{e^2}$$

From this formula we get how many water supplies we have to test to be confident of our results.

n = required number of samples

P = assumed proportion of households (HH) with “not used” toilet

D = design effect which reduces the risk of homogeneity

e = acceptable precision usually +/-0.05, here +/- 0.1

Example:

D: Design Factor: 4, P: Assumed Proportion: 0.50, E: Precision: +/- 0.1

$$n = \frac{4 * 0.5(1 - 0.5) * 4}{0.1^2} = 400$$

Thus, for achieving a 90% confidence interval we're required to test 400 samples per district

Step-2: Stratification

It has been experienced in MDAWS (Multi District Assessment of Water Safety) survey to take 10 samples from a particular Gram Panchayat (GP) while the number of villages will be decided on the basis of samples to be taken from the district divided by 10 i.e. 40.

For sampling interval (SI), population of all GPs of the district have to be written in cumulative manner and then dividing the total population of the district with the number of samples i.e. 40. As an example, if population of a district is 10,00,000 then SI would be 25,000.

If a random number like 100 has been selected sampling intervals of 1 to 25,000 then the first sample GP will be the one where 100 number falls in the population and the second GP will be the one where number 25,100 (25,000+100) falls on the population figures while the third GP will be with the number 50,100 and so on.

Step-3: Locate Sample

Once the GPs, 10 identified then water sources would be selected randomly from the GPs in a way where all habitations will be given an equal representation. In this case, India Mark-II hand pumps were chosen from these habitations for better comparison.

Apart from sampling, the following information was also collected in the following format (Table 2) for further use in GIS software. The Inverse Distance Weighted (IDW) was used as a method of interpolation that estimates cell values by averaging the values of sample data points in the neighbourhood of each processing cell. The closer a point is to the centre of the cell being estimated, the more influence, or weight, it has in the averaging process.

Table 2

General Information of selected Hand Pump

Information Head	Relevant Details
Name of Village	
Name of Gram Panchayat	
Name of Block	
Name of District	
Latitude	
Longitude	
Altitude	
Depth of water level of hand pump (m)	

Results and Discussion

The test results of water samples collected from selected villages of Allahabad District are compiled and discussed in this section. The obtained results are presented using GIS software. The quality of groundwater depends upon several factors. The most important factor, which determines the level of pollution of ground water, is the hygienic level present near the sampling site. The suitability of supply from groundwater for drinking purposes has been assessed according to guidelines laid down by Drinking Water Specifications: BIS: 10500 (91) for various water quality parameters.

Discussion on Major Critical Parameters**Fluoride**

The analysis of results shows that the fluoride concentration varied from 0.6 mg/l to 1.2 mg/l in most of the villages; however, it ranged from 0.91 to 3.46 mg/L in Kondhiyara Block. Shankargarh and Kondhiyara Block are in dangerous zones in terms of groundwater fluoride concentration, as it is above the desirable limit. The results can be visualised from Figure 2. In 1994, a World Health Organization expert committee on fluoride use stated that 1.0 mg/L should be an absolute upper bound, even in cold climates, and that 0.5 mg/L may be an appropriate lower limit. According to drinking water specification IS: 10500 (1991), the desirable limit of fluoride is 0.6 to 1.2 mg/L and limit for rejection is 1.5 mg/L (BIS 10500, 91). If the limit is below 0.6 mg/L, water should be rejected. Fluoride in drinking water has a profound effect on

teeth and bones. Fluoride up to a small level of 1.0–1.5 mg/L strengthens the enamel. Concentrations in the range of 1.5–4.0 mg/L result in dental fluorosis. With prolonged exposure at still higher fluoride concentrations (4–10 mg/L), dental fluorosis progresses to skeletal fluorosis (Mahapatra et al., 2009). Based on these guidelines, the water of Kodhiyara and Shankargarh blocks may be treated through fluoride removal plants before being supplied to people of rural areas. The use of manganese oxide coated alumina as media for fluoride containing water treatment may be one of the suitable options (Shihabudheen et al., 2006).

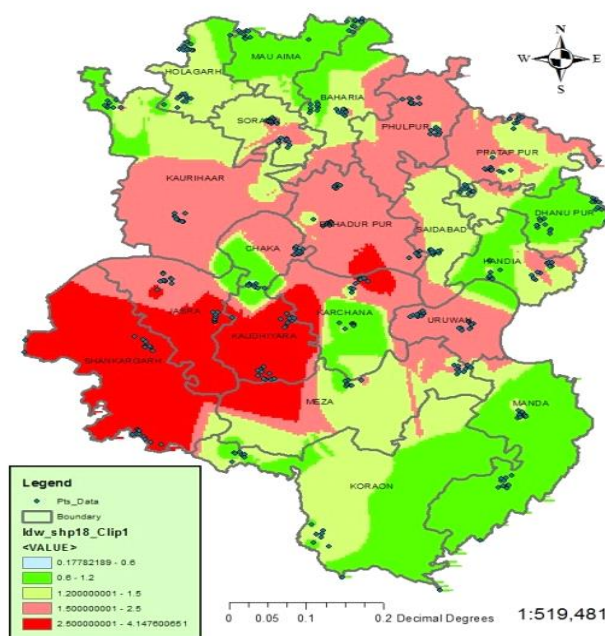


Figure 2: Distribution of Fluoride Concentrations in Different Blocks of Allahabad District

Iron

The laboratory testing results also show that maximum concentration of iron was 2.05 mg/L in Soraon Block. Shankargarh, Jasra, and Mauaima blocks also witnessed high concentration of iron. According to drinking water specification, IS:10500 (1991), the desirable limit of iron is 0.3 mg/L, and the permissible limit is 1.0 mg/L. In water samples of most of the villages of Allahabad District, the iron concentrations found were

higher than the permissible limit. The maximum values of iron in hand pump waters were recorded as 2.05, 2.02, 1.3, and 1.9 mg/L in Soraon, Shankargarh, Jasra, and Mauaima blocks respectively. High concentration of iron causes brackish color, rusty sediment, bitter or metallic taste, brown-green stains, iron bacteria, and discolored beverages. Water with high concentrations of iron cannot be used for laundry purposes because it creates staining problems. The iron removal plant followed by sand filtration may be a suitable option for removal of iron from this area's groundwater. Figure 3 shows the distribution of iron concentrations in different blocks of Allahabad District.

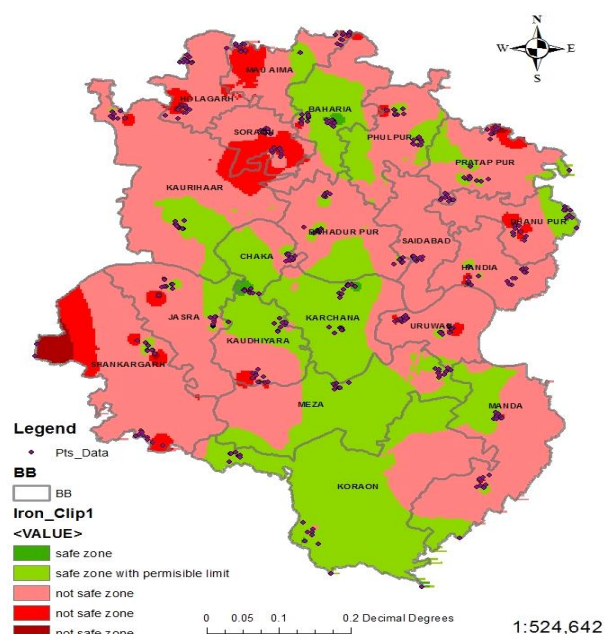


Figure 3: Distribution of Iron Concentrations in Different Blocks of Allahabad District

Total Hardness

The total hardness of water samples varied from maximum 425.2 mg/L (as CaCO_3) at Shankargarh Block to a minimum of 208.5 mg/L (as CaCO_3) at Manda Blocks. Shankargarh, Jasra, and Mauaima Blocks also recorded higher total hardness concentrations greater than the permissible limit but below the range for rejection. The results are shown graphically in Figure 4.

The range for total hardness for villages of Allahabad District are 208.5 -425.2 mg/L. It can be seen that most of the village water samples are very hard per the hardness scale. As a rule, hardness increases with total dissolved solids, and in all samples of villages, total dissolved solids was found in greater concentration than the permissible limit. The sources of hardness are dissolved calcium and magnesium from soil and aquifer minerals containing limestone or dolomite. The hard waters are as satisfactory for human consumption as soft waters. According to IS:10500 (1991), the desirable limit of total hardness as CaCO_3 is 300 mg/l and cause for rejection limit is 600 mg/l.

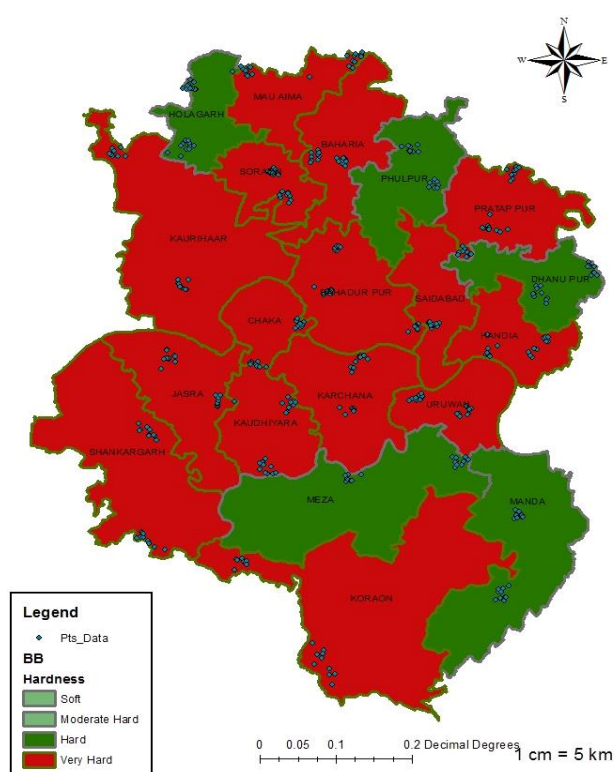


Figure 4: Distribution of Total Hardness Concentrations in Different Blocks of Allahabad District

Arsenic

The arsenic concentration in ground waters of Allahabad District was also measured during sampling to assess the risk levels of the people.

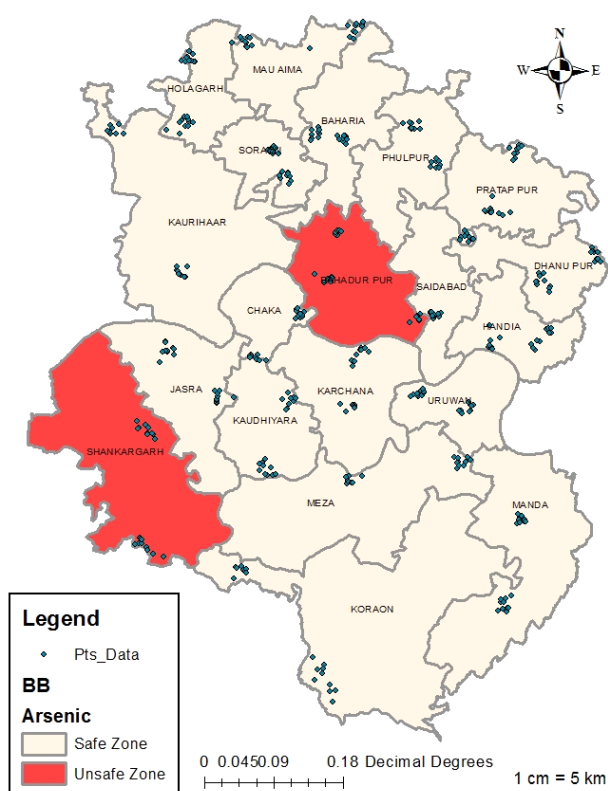


Figure 5: Distribution of Arsenic Concentrations in Different Blocks of Allahabad District

Based on the results, Shankargarh and Bahadurpur Blocks are falling in arsenic affected areas as per WHO (2003) guidelines for drinking water quality for arsenic (0.01 mg/L). Arsenic is introduced into groundwater through the dissolution of minerals. Arsenic naturally occurs in the environment as an odorless, tasteless, semi-metal element. It can get into drinking water supplies drawn from groundwater that contain arsenic from natural deposits in the earth, or from agricultural and industrial practices. Several researchers have reported exposure-response relationships for several types of cancer including urinary-bladder, kidney, lung, and skin cancer (Smith, 1998). A few studies have suggested that exposure to arsenic in drinking water is associated with cancer at additional tissue sites, such as prostate cancer in men and nasal cancer in both sexes (Smith, 1998). Arsenic water filtration is vital to many communities where arsenic has been detected at dangerous levels in public drinking water supplies. The communities are employing new strategies and technologies to keep their water supplies safe for human consumption. The iron impregnated media

is better for arsenic removal as compared with other media due to its preparation and suitability [Vaishya & Gupta, 2003(a)] The iron oxide coated sand filtration [Vaishya & Gupta, 2003(b)] may be a suitable, low-cost option for people of rural areas.

Conclusions

The present study was conducted to create a GIS based water quality mapping of Allahabad District. The results of this study showed the various water quality problem affected areas through maps in Allahabad District of Uttar Pradesh State. The numbers of blocks in rural areas affected by various water quality problems are shown through GIS maps.

The analysis showed that the concentration of fluoride in water samples varied from 0.91 to 3.46 mg/L in Shankargarh and Kondhiyara Blocks. These blocks are in danger zones due to fluoride concentration which is in excess of the permissible limit.

Iron concentration was greater than the permissible limit in more than 50% of rural habitations of Allahabad District. The maximum values of iron in hand pump waters were recorded as 2.05, 2.02, 1.3,

and 1.9 mg/L in Soraon, Shankargarh, Jasra, and Mauaima blocks respectively.

The total hardness of samples varied from maximum of 425.2 mg/L at Shankargarh Block and minimum of 208.5 mg/L at Manda Block.

The concentrations of arsenic in water samples of Shankargarh and Bahadurpur Blocks were around 0.025 mg/L which exceed the permissible limit per WHO guideline value of 0.01 mg/L.

This study may provides a sufficient quantity of scientifically sound data that is available to all in order to facilitate water quality protection of rural areas' water supply, which is mostly dependent on India Mark-II hand pumps. The data is also useful to the government of Uttar Pradesh, the Ministry of Drinking Water Supply, and for sanitation purposes in order to take all precautionary measures to safeguard public water supplies.

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References

- Bartram, J and Ballance, R. (1996), Water quality monitoring –A practical guide to the design and implementation of fresh water qualities studies and monitoring programmes, *UNEP/WHO report*, ISBN 0419223207 (Hbk).
- BIS, Drinking water standards (1991) (IS 10500) *Bureau of Indian Standard*, India.
- Mohapatra, M., Anand S., Mishra B.K., Giles D.E. and Singh, P. (2009), "Review of fluoride removal from drinking water", *J. Environ. Manage.* 91, 67–77.
- Shihabudheen M. M., Sharma, A.K. and Philip, L. (2006), "Manganese-oxide-coated alumina: A promising sorbent for defluoridation of water", *Water Research* 40, 3497-3506.
- Smith A.H., Goycolea M, Haque R., Biggs M.L. (1998), "Marked increase in bladder and lung cancer mortality in a region of northern chile due to arsenic in drinking water", *Am. J. Epidemiol.*, 147, 660-669.
- Standard Methods for the examination of water and wastewater (1989), 17th Ed. *Am. Public Health Assoc.*, Washington D.C.
- Vaishya, R. C., & Gupta, S. K. (2003, a), "Arsenic removal from groundwater by iron impregnated sand", *Journal of Environmental Engineering*, 129, 89-92.
- Vaishya, R.C. and Gupta, S.K. (2003,b), "Coated sand filtration: An emerging technology for water Treatment", *Journal of Water Supply: Research and Technology-AQUA*, 52, 299-306.
- WHO (2003), *Guidelines for Drinking Water Quality Recommendations*, World Health Organization, Geneve.